

# HydroQual, Inc.

CONSULTANTS IN WATER POLLUTION CONTROL

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Mr. John Laumer  
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RECEIVED OCT 22 1981

Dear Mr. Laumer:

As per our conversation of this morning, I am enclosing our final contribution to Waukegan EIS. In this effort we attempted to incorporate all comments to the extent that it was possible. We would be very much interested in receiving a copy of the final EIS.

It was a pleasure working with you on this project, and hope to be of service to Wapora, Inc. in the future.

Very truly yours,

HYDROQUAL, INC.

*Michael T. Kontaxis*

Michael T. Kontaxis

MTK/lmz  
Enclosure

## 1.2 Magnitude of PCB Contamination

The purpose of this section is to present available PCB data for the water column and bed sediment of Waukegan Harbor, North Ditch and the near shore area of Lake Michigan, as detailed in sections 1.2.1.1, 1.2.1.2, 1.2.1.3, respectively. On the basis of these data, estimates of PCB mass in the bed sediments of Waukegan Harbor and North Ditch are made. In what follows, the term "sediment" refers to PCB contaminated material in the bottom of the Waukegan Harbor whereas the term "soil" refers to PCB contaminated material associated with the North Ditch. The PCB concentration on sediments and soils is expressed, herein, in " $\mu\text{g/g}$ " which stands for microgram (= millionth of a gram) of PCB per gram of dry weight sediment or soil. On a mass basis the " $\mu\text{g/g}$ " unit is equivalent to "ppm".

### 1.2.1 Amount and Distribution of PCBs in the Project Area

Two estimates of the mass of PCB in Harbor/Ditch system were made, one by HydroQual, Inc., (1981), and one by Mason and Hanger (1981). These estimates are shown in Table 1.1 and Table 1.2 respectively. The variability in the estimates stems primarily from the different methods of grouping and averaging field data of PCB contamination, also, the estimates in Table 1.1 do not include the PCB mass under the OMC parking lot and the banks of the North Ditch. It must be emphasized, however, that both methods estimate a very large mass of PCB, in the order of several hundred thousands of pounds.

The distribution of this large mass of PCB is important because the spatial distribution of the PCB mass and the spatial distribution of the PCB concentration in the bed sediments are at the base of a formulation of action alternatives. Figure 1 shows the distribution of the PCB mass in the sediments of four areas in Waukegan Harbor. Areas A, B, C, are important since they are involved in the formulation of the various action alternatives. From this figure it follows that, by both estimates, more than 95% of the total PCB sediment mass is located in Area A or Slip 3. From the same Figure it follows that more than 98% of the total PCB sediment mass is located in Areas A and B combined. It is very important to emphasize that Areas A and B combined contain all the sediments with PCB contamination greater than 50 ppm.

#### 1.2.1.1. Harbor Sediments and Water

Various surveys of the Harbor have provided data to assess bed sediment PCB contamination. The most significant surveys by agency and date are given below:

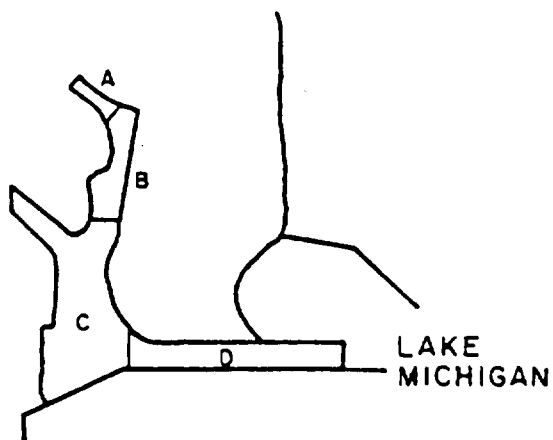
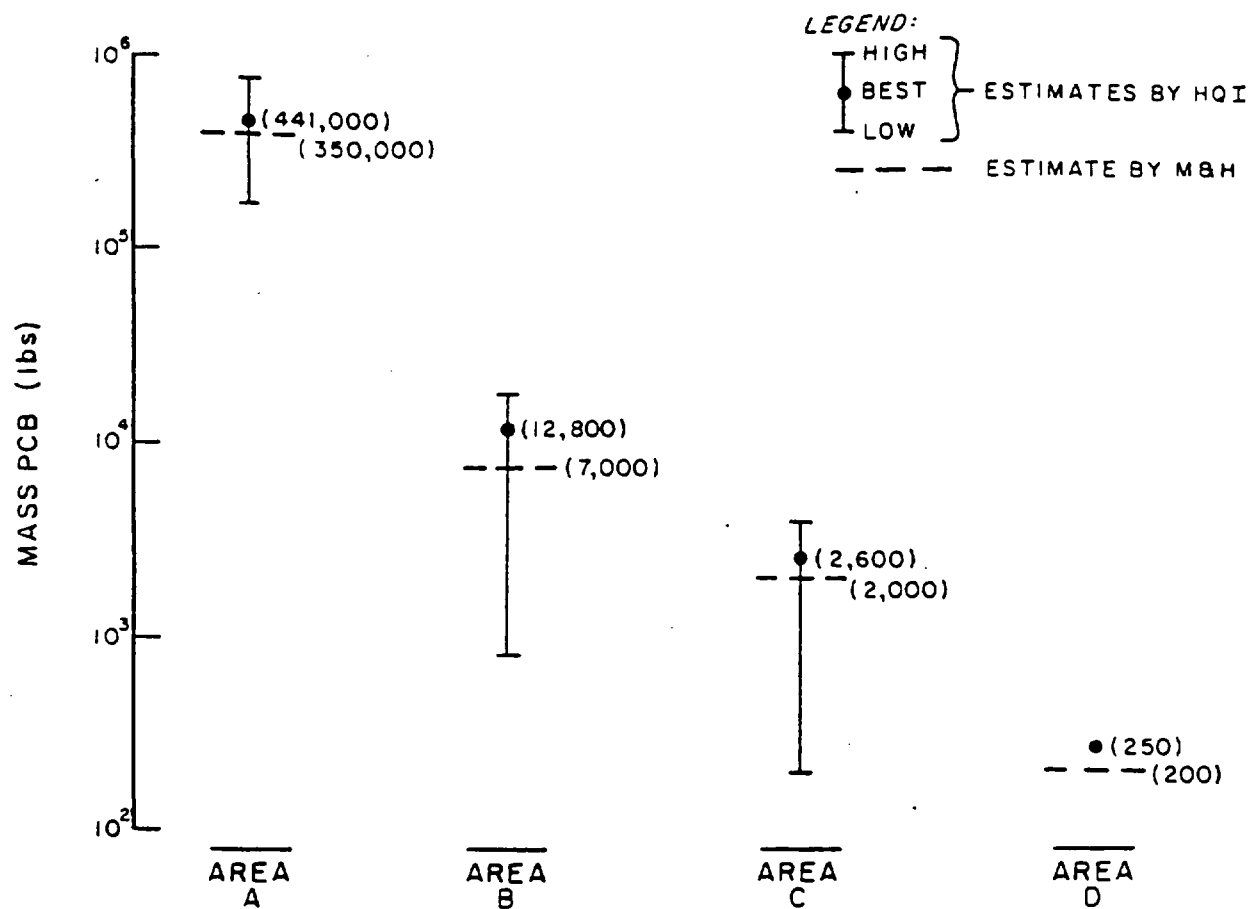


FIGURE 1  
DISTRIBUTION OF SEDIMENT PCB MASS IN WAUKEGAN HARBOR

TABLE 1.1

ESTIMATES OF PCB MASS IN THE SEDIMENTS OF  
WAUKEGAN HARBOR AND NORTH DITCH SOILS  
BY HYDROQUAL, INC.

	Best Estimate	High Estimate	Low Estimate
Waukegan Harbor	456,650 lbs	756,980 lbs	166,790 lbs
North Ditch	611,580 lbs	1,163,100 lbs	189,330 lbs
Total	1,068,230 lbs	1,920,080 lbs	276,610 lbs

TABLE 1.2

ESTIMATES OF PCB MASS IN THE SEDIMENTS  
OF WAUKEGAN HARBOR SEDIMENTS AND NORTH DITCH SOILS  
BY MASON AND HANGER

Waukegan Harbor Sediments	359,200 lbs
North Ditch Soils	775,000 lbs
Total	1,134,200 lbs

<u>Agency</u>	<u>Date</u>
U. S. EPA	May, June, 1976
State of Illinois	February, 1977
ENCOTEC, Inc.	April, 1977
Univ. of Wisconsin	September, 1978
U. S. EPA & ERG, Inc.	July, 1979
Mason and Hanger, Inc. )	
Warzyn Engineering, Inc.)	November, 1980
Raltech, Inc. )	

The results of these surveys are summarized and discussed in Mason and Hanger (1981). Figure 2 is a plot of surface sediment PCB data in Waukegan Harbor. At the innermost Harbor locations, Slip 3 values ranged from 100 to 10,000  $\mu\text{g PCB/g}$  (dry). Concentrations then decreased to a range from 0.1 to 10  $\mu\text{g/g}$  at the Harbor mouth. These values compare to a range of PCB surface sediment concentrations for open Lake Michigan of .01 - 0.1  $\mu\text{g/g}$  (IJC, 1978). It is important to note that there is no discernable difference between the data collected during 1976-78 and during 1979.

A number of data collection surveys off Waukegan Harbor and adjacent areas of Lake Michigan were performed during 1979 by USEPA, Argonne National Laboratories and others. Weekly samples were taken at six harbor stations and three nearshore Lake Michigan stations by USEPA over about a two month period. Samples were analyzed for suspended solids, total PCB and particulate PCB. On two U. S. EPA surveys, May 15-17 and June 26-28, 1979, surface sediment and suspended solids were fractionated into four size classes. The PCB associated with each size class (as well as total PCB and dissolved PCB) were measured. Argonne conducted daily surveys sampling six Harbor stations, surface and bottom, for 18 days, May, 1979. Temperature, chlorides, lead, suspended solids and total PCB (surface only) were measured. Argonne also conducted an instantaneous release dye study in early June of 1979.

Figure 3 shows the concentration of total PCB in the water column along a centerline transect through the Harbor. These concentrations were calculated from the daily data during the period from 5/2/79 to 5/19/79. The water column total PCB concentrations are expressed in " $\mu\text{g/l}$ " which stands for a microgram (= millionth of a gram) per liter of water. The analysis of the daily data shows large day to day variations in the total PCB concentration. In Figure 3 the average total PCB concentration in Slip 3 is approximately 10 times larger than the average total PCB concentration at the mouth of the Harbor. The few data in the lake would indicate that the total PCB concentration there is about 10 times less than the total PCB concentration at the mouth of the Harbor.

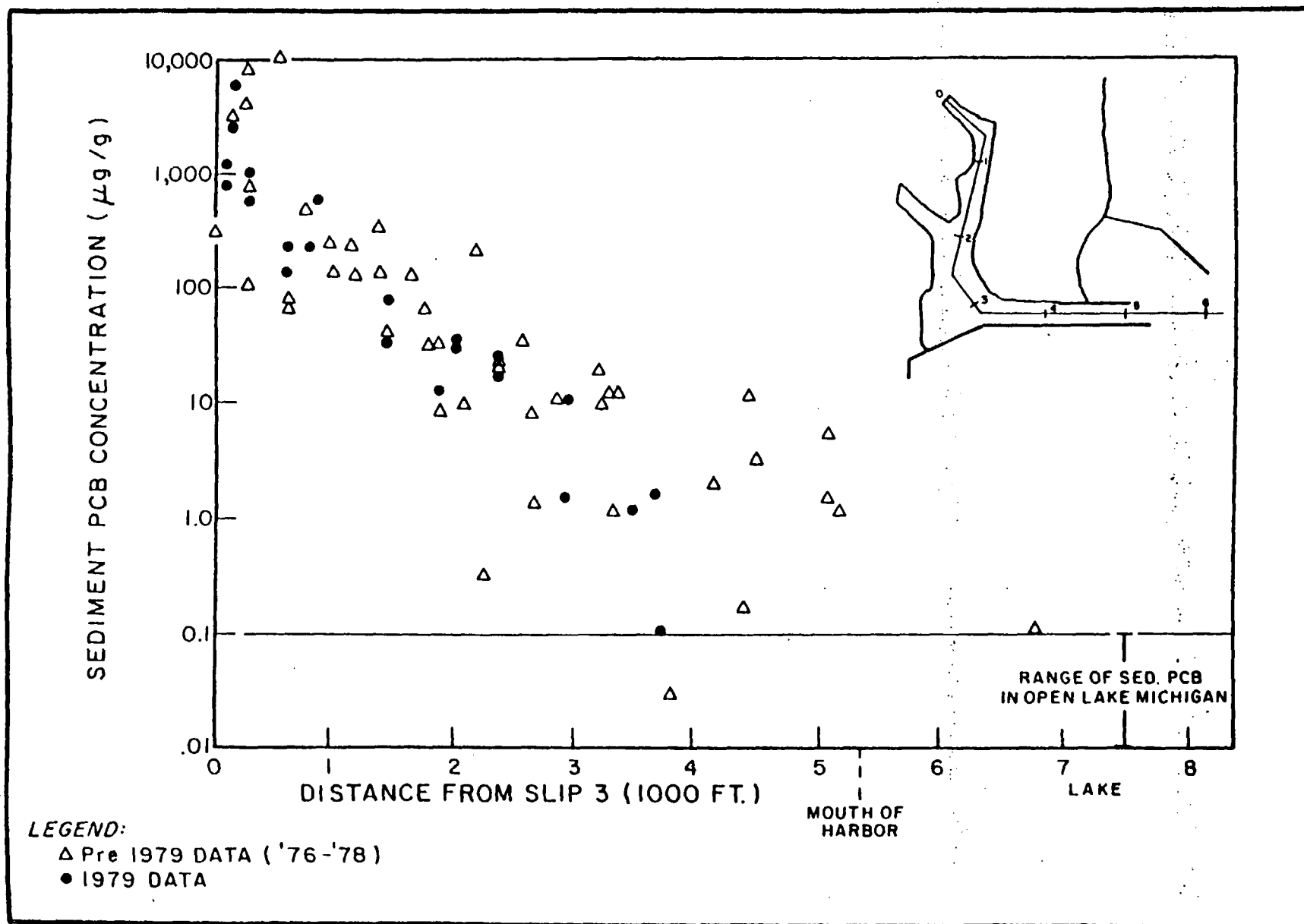


FIGURE 2  
SURFACE SEDIMENT PCB CONCENTRATION

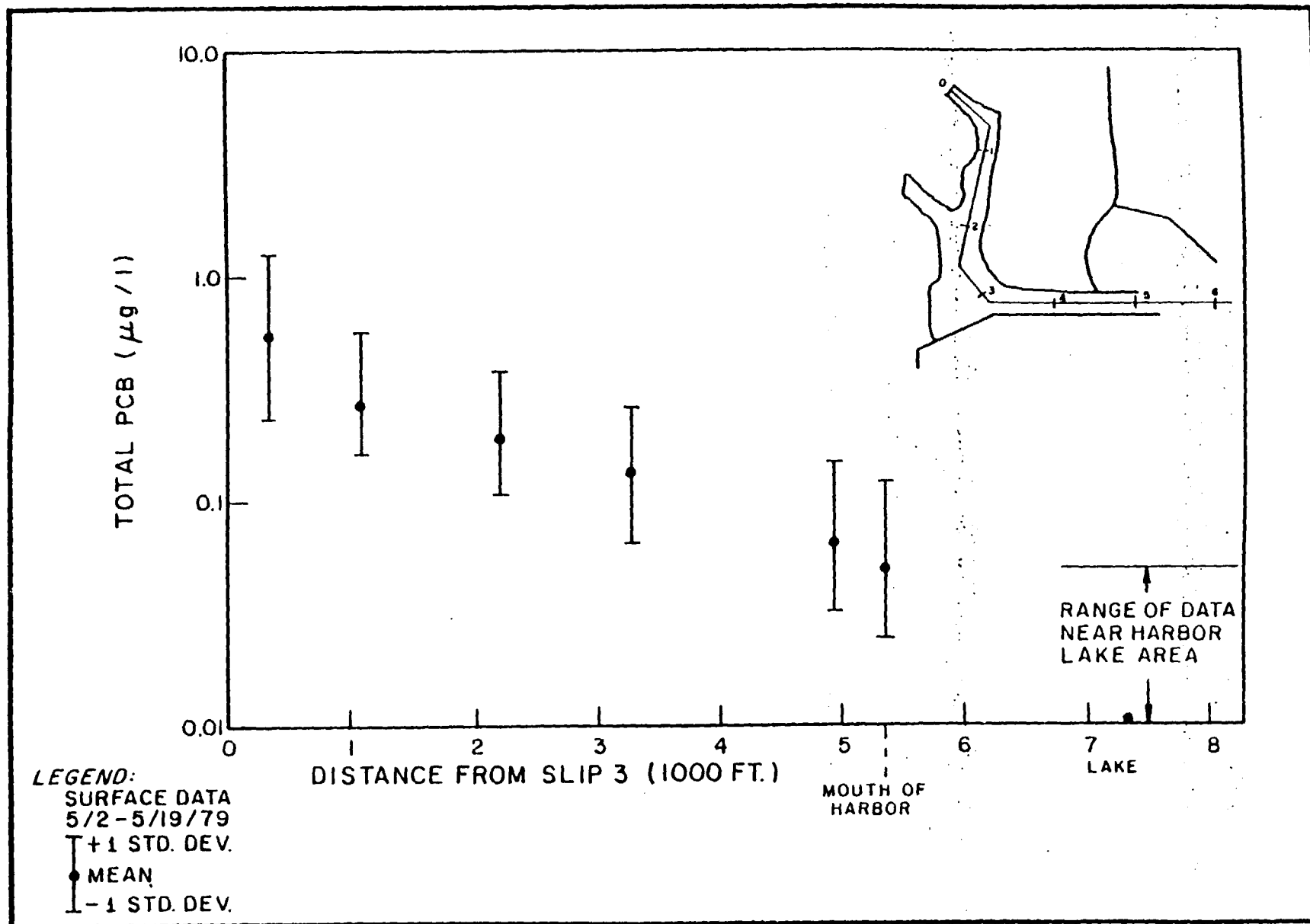


FIGURE 3

WATER COLUMN TOTAL PCB DURING THE DAILY SURVEY PERIOD

#### 1.2.1.2 North Ditch Soils and Water

Tables 1.1 and 1.2 indicate that at least 50% of all the PCB in the Harbor/Ditch system are associated with the North Ditch. Furthermore, since more than 95% of all the PCB contaminated soils under the North Ditch, excluding the parking lot soils, are located in the Crescent and Oval Lagoon sections of the Ditch, it implies that the degree of PCB contamination of these sections is greater than that of the Slip 3 in the Harbor.

Two principal references (Battelle, undated, Mason and Hanger, 1981) provided data on concentrations of PCB in the soils of the North Ditch.

The only PCB water column data resulted from a study examining sediment transport in the Ditch (Noehre & Graf, 1980). The survey extended from March to November, 1979, and the majority of PCB data were collected at the footbridge, a point on the North Ditch located approximately 200 feet above the mouth of the Ditch. Figure 4 gives a summary of all the available data. For that period of record the average total PCB concentration is 9.25  $\mu\text{g/l}$  which is approximately 100 times greater than the average PCB concentration near the mouth of the Harbor, Figure 3.

#### 1.2.1.3 Lake Michigan Water and Sediments Near Waukegan

Some water column samples near the mouth of the Harbor have been collected in Lake Michigan during some of the Harbor surveys. Within this near Harbor area, less than 1 mile from the harbor mouth, the observed total PCB concentrations are in the range of .01 to .05  $\mu\text{g/l}$  (HydroQual, 1981), as shown in Figure 3.

The surface bottom sediments of the near Harbor area have been sampled in greater spatial detail (Armstrong, 1980). The concentrations decrease with increasing distance from the Harbor mouth. At stations near the Harbor mouth the PCB sediment concentrations varied between about 25-89 ng/g (dry) while at the further away station the concentrations decreased to the 5 to 22 ng/g range (Figure 2). The unit "ng/g" stands for nanogram (= billionth of 1 gram) of PCB per gram of dry weight sediment. The "ng/g" unit is 1000 times less than the " $\mu\text{g/g}$ " unit.

#### 1.2.2 Movement of PCBs into Lake Michigan

The present average total PCB mass input from steady state and storm events from the Harbor/Ditch system to Lake Michigan has been estimated by HydroQual, Inc. (1981) as 22-44 lbs/yr. The application of the Waukegan Harbor model indicates a steady state PCB mass input of 8.8 lb/yr from the Harbor to Lake Michigan.

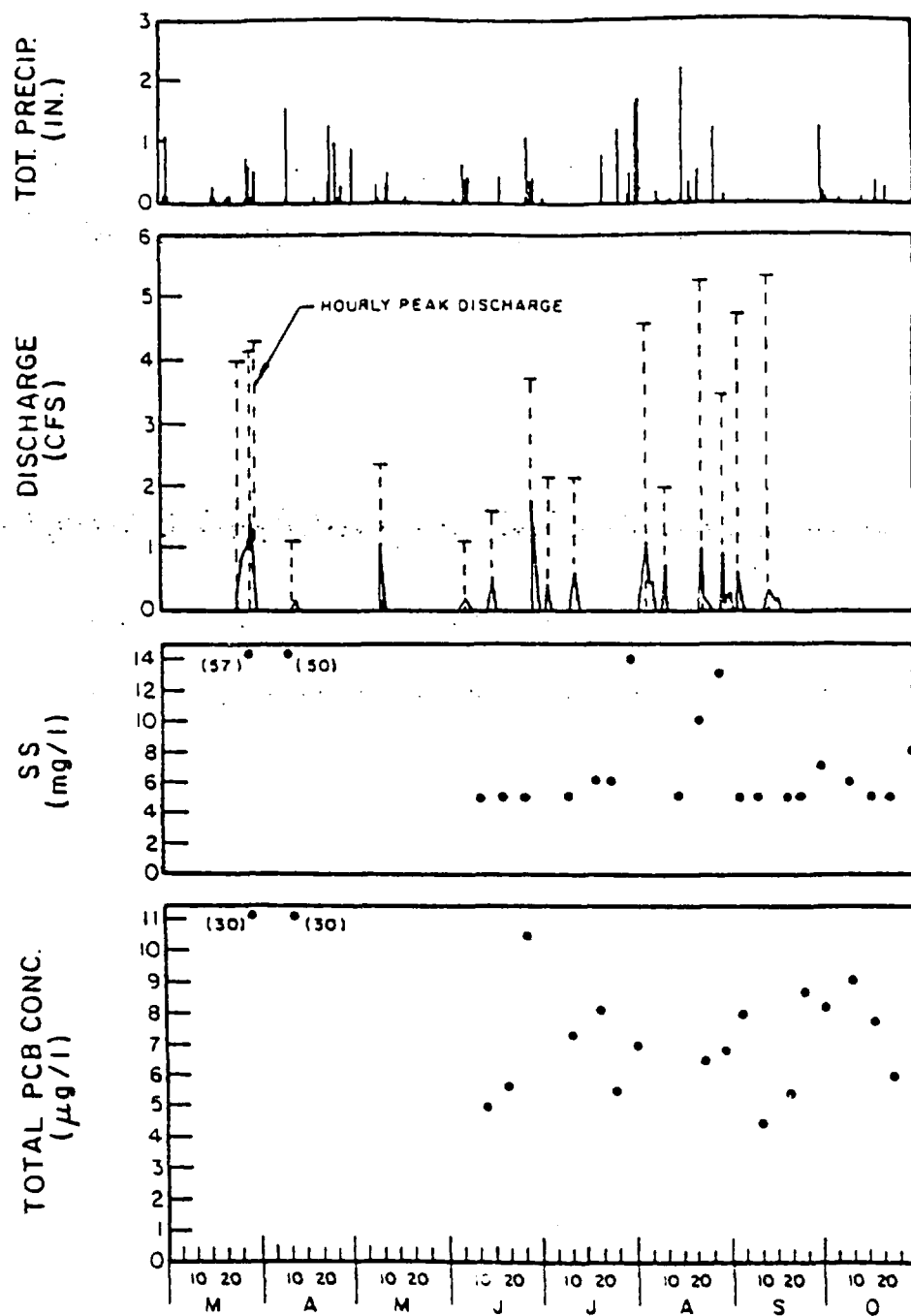


FIGURE 4

DATA RECORD FOR MARCH TO NOVEMBER, 1979  
AT GAGE 1 (FOOTBRIDGE)

The Argonne National Laboratories (1979) data suggest that periodically there are occasions during which the prevailing conditions essentially flush out the Harbor. This type of mass input from the Harbor to the Lake is the aforementioned storm-related input. On the basis of the model calculated profile in the Harbor, Figure 3, the mass input is estimated as 0.51 lb per event. A separate analysis, utilizing a hydrodynamic model of the harbor (Paul, 1981) estimates the mass input to the Lake during the same event as 0.225 kg or 0.50 lb. In the same work, (Paul, 1981) for extreme-flow events in the channel section of the Harbor caused by 67-78 mph winds, mass inputs of 11.5 kg or 25.4 lbs, are calculated. There are no estimates of the frequency of occurrence of either event in the work by Paul (1981).

HydroQual (1981) assumed that the flush-out event occurs once every two weeks and on the basis of that assumption, the storm-related input to the lake is estimated as 13.2 lbs/yr. Additional model runs with increased sediment resuspension in the harbor to simulate extreme runoff events showed increased PCB concentrations in the inner Harbor which decreased at the Harbor mouth, due to settling, thus contributing few additional pounds (less than 3) of PCB input to the Lake. The frequency of such events was not estimated. The total estimate of the PCB mass input from the harbor to the Lake is estimated as 22 lbs/yr.

HydroQual (1981) estimated the PCB mass inputs to the Lake from the North Ditch, using the model it developed for the North Ditch. The steady state simulation estimates a mass input of 4.4 lbs/yr of PCB from the Ditch. From an analysis of the precipitation record during the data collection in the North Ditch, Figure 4, and rainfall statistics of the area, HydroQual (1981), estimated that a runoff flow of 5 cfs in the Ditch represent a maximum runoff event for an average year and about 30% of the absolute maximum daily runoff expected over a long period of time. The PCB mass input from the Ditch to Lake associated with such an event is estimated (HydroQual, 1981) 6.6 lbs/yr. Sensitivity runs of the Ditch model indicate that for the runoff events in the North Ditch the resulting mass inputs are proportional to the resuspension of the bottom sediment, assuming high but constant settling velocity. The total estimate of the PCB mass input from the Ditch to the Lake is estimated as 11 lbs/yr. Adding the inputs from the Harbor and the Ditch as estimated above and allowing for the uncertainties in the frequencies of the runoff events the combined PCB mass input from the Harbor/Ditch system is given as a range, i.e. 22-44 lbs/yr.

The magnitude of this mass input can be placed into a proper perspective by comparing it to PCB mass inputs from other sources. In forming such a comparison, however, an appropriate spatial scale of impact must be established. The upper bound of such a scale is the whole of Lake Michigan. On such a scale any single point mass input is dwarfed in comparison to the load from

precipitation. A more important comparison of the PCB mass inputs is made on a near-shore basis. A near-shore sector is an area of the lake adjacent to the shore behaving as a water body somewhat independent of the main volume of Lake Michigan. Since stratification starts at 5 to 10 km offshore, the near-shore sector was taken as the lake part of the circle of radius 10 km (6.2 miles) entered at the mouth of the Waukegan Harbor.

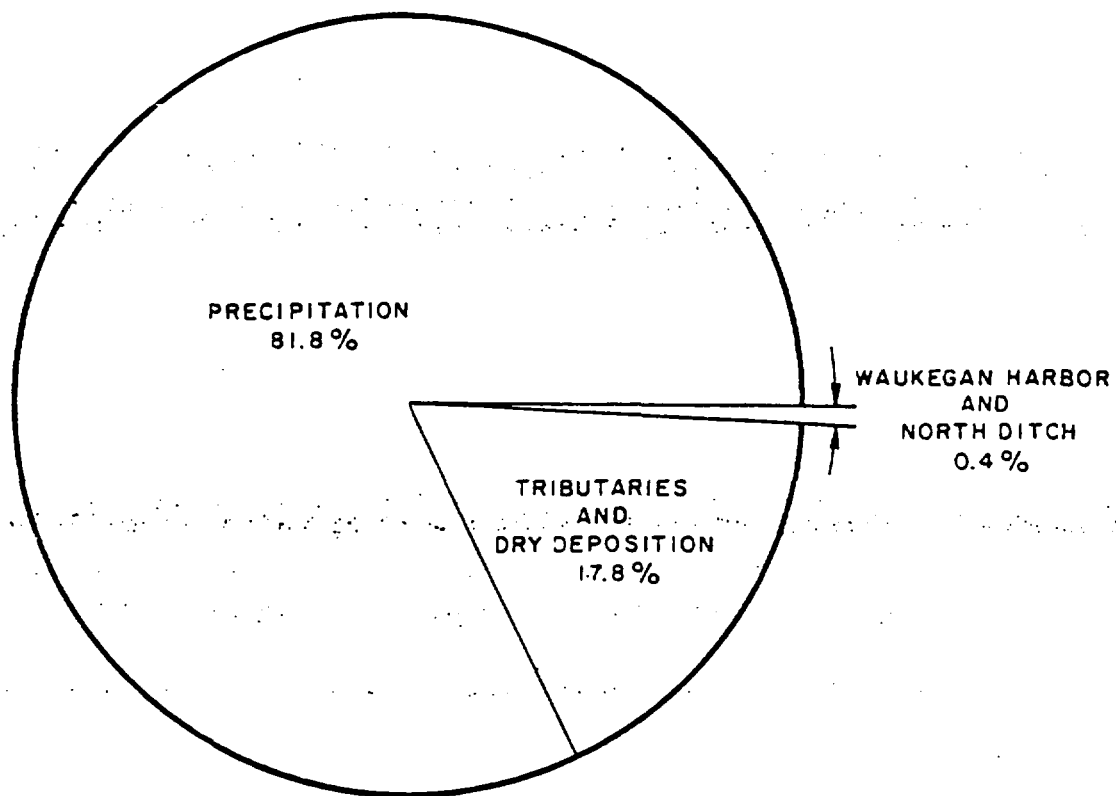
Figure 5 shows the comparison of the PCB mass inputs to Lake Michigan. The relative sizes of the circles and sectors in Figures 5 and 6 reflect the relative magnitudes of the total mass inputs. The range in estimated total mass input follows from the range in PCB concentration in the precipitation.

Various estimates of the present total PCB mass input to the whole of Lake Michigan have been made (e.g., Murphy and Rzeszutko, 1978) which give a range of 50-100 ng/l in precipitation. The unit "ng/l" stands for nanogram (= billionth of a gram) per liter of water. Strachan and Huneault (1979) reported a mean value of 21 ng/l from measurement of total PCB concentration in precipitation in the Great Lakes area, not including Lake Michigan. For a range of concentration of 20-100 ng/l, the PCB load from precipitation to Lake Michigan is about 2,000-10,100 lbs/yr. Additional inputs from dry deposition and tributaries to the Lake are estimated to account for about 1,100-2,200 lbs/yr. The total present mass input therefore to Lake Michigan is about 3,100-12,300 lbs/yr of total PCB.

It should be noted, however, that the same load becomes a significant percent of the total load to the near-shore sector of the lake immediately adjacent to the Harbor/Ditch system. Assuming that the dry deposition load to the entire Lake is about 550-1,100 lbs/yr and that rainfall and dry deposition are uniform over the Lake, then the 44 lbs/yr PCB load from the Harbor/Ditch system can be about 49-80% of the load to the near shore sector as shown in Figure 6. From this Figure it follows that the Harbor/Ditch system provides the dominant mass input to the 10 km (6.2 mi) near-shore sector.

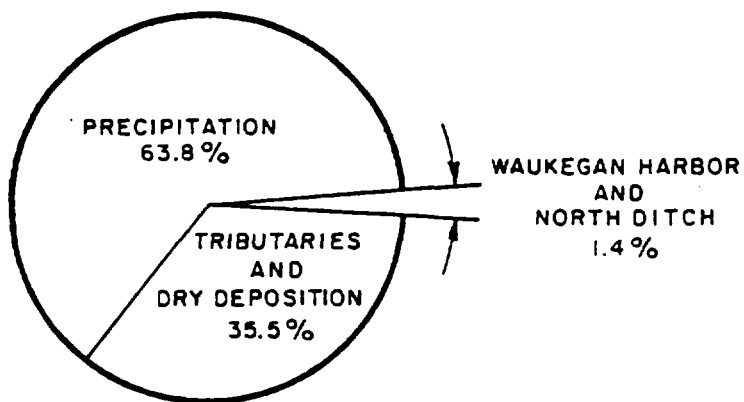
It is concluded therefore that on a whole-lake comparison, the present discharge from the Waukegan Harbor/Ditch system amounts to, at most, 1% of the total PCB mass input to Lake Michigan. On a near-shore comparison, however, (where the near shore region encompasses a 10 km (6.2 mi) radius around Waukegan Harbor), the present PCB mass input from the Harbor/Ditch system is quite significant and represents 49-80% of the total PCB mass input to this area.

TOTAL  
INPUT: 12,300 lbs/yr



(HIGH ESTIMATE OF PRECIP. INPUT.)

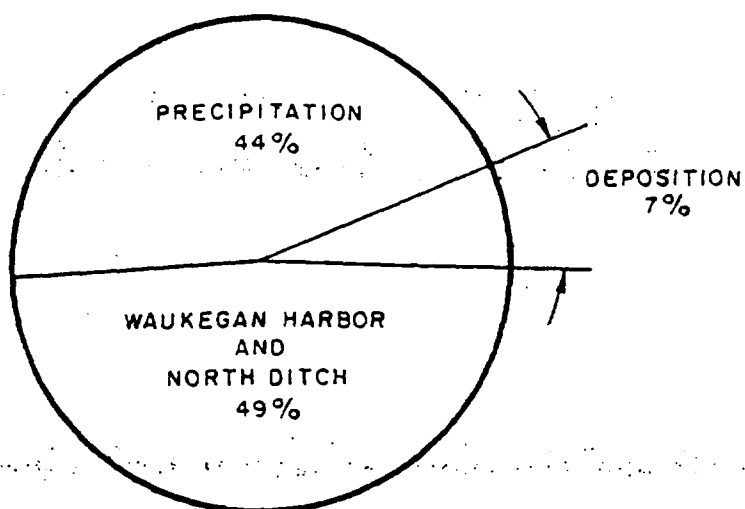
TOTAL  
INPUT: 3,100 lbs/yr



(LOW ESTIMATE OF PRECIP. INPUT.)

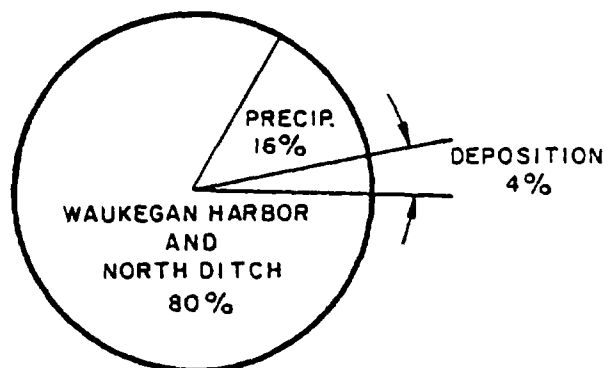
FIGURE 5  
RANGE AND DISTRIBUTION OF PCB INPUTS TO LAKE MICHIGAN

TOTAL  
INPUT: 90 lbs/yr



(HIGH ESTIMATE OF PRECIP. INPUT.)

TOTAL  
INPUT: 55 lbs/yr



(LOW ESTIMATE OF PRECIP. INPUT.)

FIGURE 6

RANGE AND DISTRIBUTION OF PCB INPUTS TO SECTOR  
OF LAKE MICHIGAN ADJACENT TO WAUKEGAN HARBOR

#### 1.2.4.2 Predicted Accumulation of PCB in Fish in Waukegan Harbor Vicinity

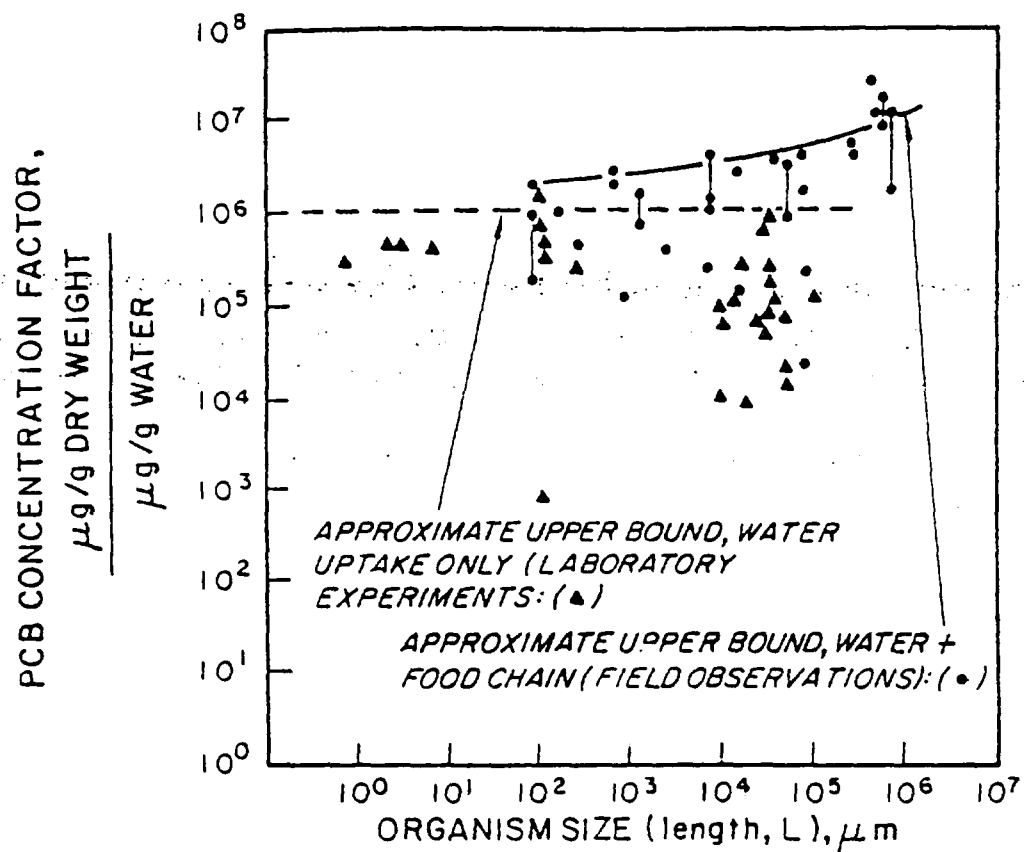
One of the major concerns of the discharge of PCBs to a system such as Waukegan Harbor is the potential for accumulation of the chemical by the aquatic food chain and subsequent potential transfer to man through intake of contaminated fish. A considerable and growing literature exists on the accumulation of PCBs by various aquatic organisms. Thomann (1981) has compiled much of this literature with the specific aim of determining the relative amount of PCB that would be concentrated by an aquatic organism directly from the water and the amount of PCB that would be accumulated through ingestion of contaminated prey. The relative amount of PCB in the organism compared to that in the water is called the concentration factor. This factor varies depending on whether the organism obtains its PCB from either water or food or both.

Figure 7 (Thomann, 1981) indicates the comparison of these concentration factors from different waters throughout the world. The data appear to show a clear divergence between the amount of PCB taken up from the water only and that accumulated from both the water and the food chain. At organism sizes of about 0.1 m (about 4 inches), the small fish, the bioaccumulation factor is about  $10^{5.6}$   $\mu\text{g/g}$  (dry) per  $\mu\text{g/g}$  (water) or about 4 times higher than the factor from water alone. The difference is attributed to the predation of contaminated prey, the low excretion rate of PCBs and a hypothesized high absorption rate of PCB from the food.

Figure 7 also shows that for the larger fish of about 0.5 meters (about 20 inches long), the data from the different water bodies indicate a substantial increase in the amount of PCB in the fish relative to water. This increase is attributed to the consumption of PCB contaminated prey and the longer life spans of some of the larger organisms. It was concluded from the data that PCBs may enter important fish species through two routes; directly from the water and also from the food route.

For Waukegan Harbor, data on the PCB concentration in fish have been compiled from several sources (U. S. EPA 1979, a, b, 1981; Steiner, 1979, and Veith, 1980). These sources reported the following species were collected in Waukegan Harbor in various locations:

- Largemouth and Smallmouth Bass
- Sunfish, Crappie
- Shiners
- Alewife
- Yellow Perch
- Rainbow Trout
- Bullhead
- Sucker
- Carp



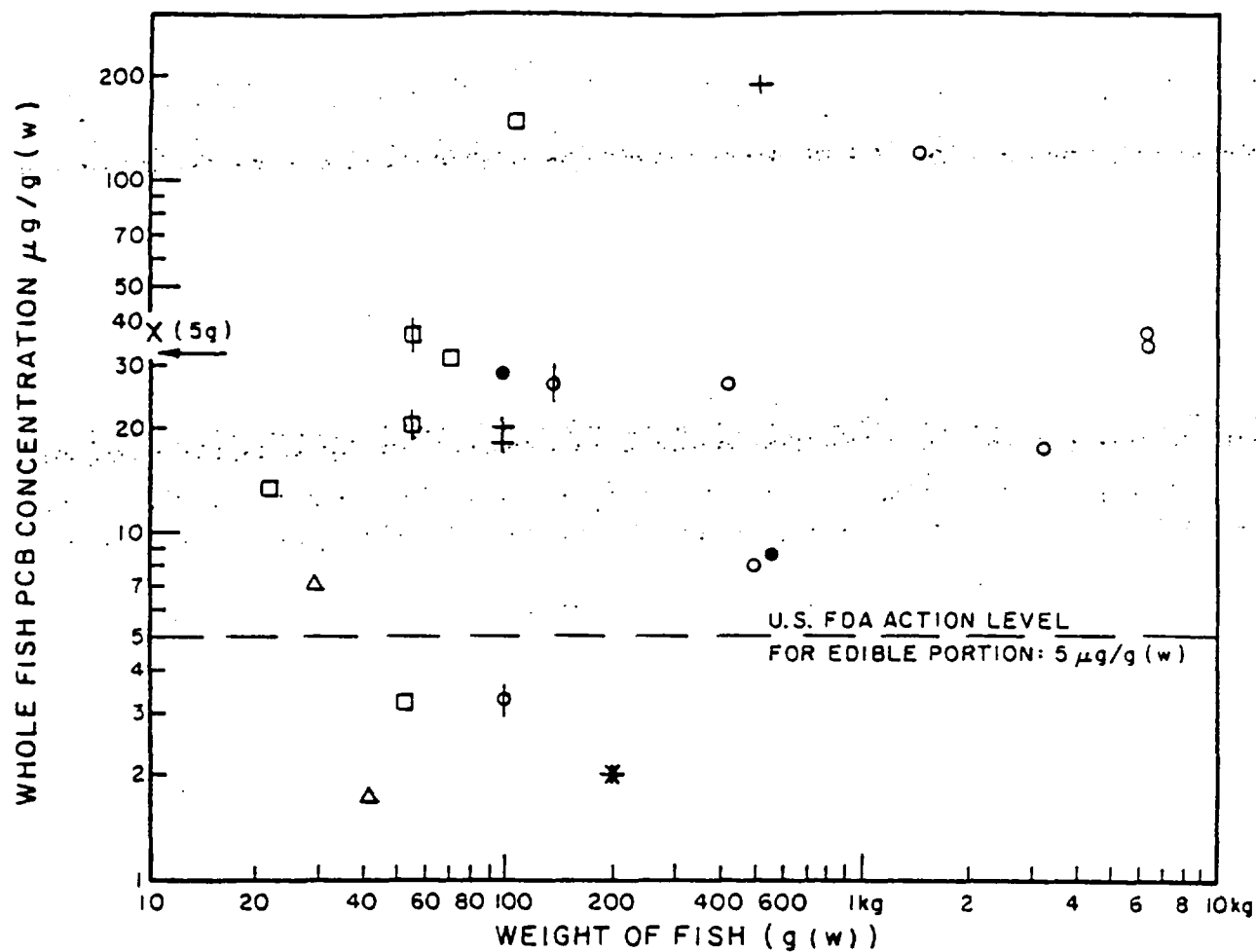
REFERENCE:  
 AFTER THOMANN (1981)

FIGURE 7  
 EVALUATION OF CONCENTRATION FACTORS

Figure 8 is a plot of the whole fish PCB concentration (in  $\mu\text{g PCB/g(w)}$ ;  $\text{g(w)} = \text{grams wet weight}$ ) in the fish versus the weight of the fish for all of the species that were collected. Several points can be noted. (1) About 80% of the total number (or group) of fish for which PCB were measured (23) had concentrations above the U. S. FDA action level of  $5 \mu\text{g/g (w)}$  for the edible portion. The comparison between whole fish and edible portion is not entirely direct, but one would normally expect the edible portion to be at the least about 20% of the whole body concentration. (2) Some fish carry extremely high concentrations of PCB of greater than  $100 \mu\text{g/g (w)}$ . In general, the range of concentrations for all species of from  $2 \mu\text{g/g}$  to  $187 \mu\text{g/g}$  is approximately similar to the order of magnitude observed for the Hudson River and estuary (Hydroscience, 1979), a water body that is considered to be a highly contaminated PCB problem area. (3) There is a considerable scatter in the data undoubtedly reflecting the exposure of the fish to varying concentrations in the Harbor. There is a slight tendency for larger fish (e.g. greater than about  $254 \text{ g (1 lb)}$ ) to have high concentrations. The variation in the concentration of each species is also dependent on the lipid content of the fish and its feeding behavior. For example, carp are bottom detritus feeders and, therefore, interact with the sediment and its associated PCB concentrations. Largemouth bass are carnivorous predators and may bioaccumulate PCB more markedly because of their higher position in the food chain.

It is important to analyze the relationship between the water concentration of PCB and the resulting concentration in the fish in order to estimate the response of the fish to possible reductions in the water concentrations. Although other important fishes such as the lake trout and coho salmon have been obtained in the waters off-shore of Waukegan Harbor (Vidal, 1979; Vidal, 1980; Hess, 1980), there are only limited data to indicate any significant occurrence of these fishes in Waukegan Harbor proper. Vidal (1979) reported that dead mature chinook salmon were observed in Waukegan Harbor in October 1975 and September 1976. In addition, no data in the PCB content of the fishes, in the Harbor proper, is available. Therefore, it is not possible to estimate the relationship between fishes such as lake trout which may only transiently inhabit the Harbor and the PCB contamination in the Harbor.

For the near shore environment, a lack of detailed PCB data also precludes an in-depth evaluation of the PCB water concentration and off-shore fishes. In general, the PCB concentrations in the waters immediately outside the Harbor (i.e. within approximately a  $1 \text{ km}$  radius) is about  $.01-.02 \mu\text{g/l}$  and then drops rapidly to open lake values of  $.005-.01 \mu\text{g/l}$ . One would normally expect, on the basis of these water



LEGEND:

- O - CARP
- - BULLHEAD
- ⊙ - SUCKER
- + - BASS (Lg. & Sm.)
- - SUNFISH AND CRAPPIE
- x - SHINERS
- Δ - ALEWIFE
- ⊕ - YELLOW PERCH
- \* - RAINBOW TROUT

FIGURE 8

PCB CONCENTRATION IN FISH COLLECTED FROM WAUKEGAN HARBOR

concentrations, that fish concentrations would be lower compared to those within the Harbor proper. This tends to be true for the PCB concentration of the smaller fish that have been measured offshore of Waukegan. For example, Muench (1980) reported a value of 0.49  $\mu\text{g/g}$  (w) of 1254 PCB for chub off of Waukegan. However, lake trout collected off Waukegan Harbor in depths of about 10-30 meters were reported to have PCB concentrations (fillet with skin) of 0.5-5.4  $\mu\text{g/g}$  (w) during 1978-1980 (Hess and Muench, 1980). The concentrations in lake trout may reach the higher levels due to food chain accumulation. Because of the limited occurrence of open lake fish such as lake trout in Waukegan Harbor and the lack of detailed data on the PCB concentrations in fish caught in the near-shore area, the analysis discussed below is limited only to those fish that have been caught in the Waukegan Harbor proper and for which PCB data are available.

The analysis framework follows the model given in Thomann (1981). Four representative fish are examined:

1. Alewife
2. Yellow Perch
3. Carp at 0.5 kg and 5.0 kg size
4. Largemouth Bass

Based on the data shown in Figure 7, it is assumed that the bioconcentration factor (i.e. uptake from the water only) across all levels of the food chain is 100  $\mu\text{g PCB/g(w)}$  in the organism per  $\mu\text{g PCB/l}$  in the water. The food chain is assumed to have the following components:

1. Level 1 - Phytoplankton and detritus which absorb or adsorb PCB directly from the water.
2. Level 2 - This level is represented by the zooplankton which take up PCB from the water but also can accumulate PCB from consuming phytoplankton.
3. Level 3 - Fish which consume zooplankton or other organisms representative of Level 2. The fish assumed in this group are: alewife, yellow perch, carp.
4. Level 4 - Fish which consume smaller fish and therefore represent a carnivorous level in the food chain. Largemouth bass is considered at this level.

Using reasonable assumptions on growth rate, specific consumption of food and excretion rate of PCB, one can derive relationships between the PCB concentrations in the organisms at a given food chain level and the PCB concentration in the water. For level 2, this leads to the following simple equation:

$$C_2 \sim 190 C_w \quad (1)$$

where  $C_2$  is the concentration of PCB in the organism of the second food chain level (e.g. zooplankton) in  $\mu\text{g PCB/g(w)}$  and  $C_w$  is the dissolved PCB concentration in the water in  $\mu\text{g PCB/l}$ . For level 3, the intermediate level of the food chain, a series of relationships are derived for each species, i.e.

$$\begin{aligned} \text{Alewife:} & C_3 \sim 510 C_w \\ \text{Yellow Perch:} & C_3 \sim 380 C_w \\ \text{Carp (0.5 kg):} & C_3 \sim 460 C_w \\ \text{Carp (5.0 kg):} & C_3 \sim 710 C_w \end{aligned}$$

In the relationships, no direct relationship of the carp with the sediment is included. The understanding of the degree to which carp would accumulate PCB from the sediments is not sufficient for such an interaction to be incorporated. For level 4, represented by the largemouth bass, the following equation is estimated.

$$C_4 \sim 730 C_w$$

In each of the equations, the feeding is assumed to be on the food chain level below and uptake from water is also included. It should be stressed that these relationships are only approximate and reflect the incorporation of approximate weight gains, feeding and excretion rates.

These relationships are shown in Figure 9. This Figure presents the results of the food chain model in such a way that one relates the PCB concentration in fish species of Waukegan Harbor to the water PCB concentration. This type of a plot allows for the assessment of the impact on PCB concentration in fish resulting from a change in the water PCB concentration. It is seen that for the present range of water concentration in Waukegan Harbor, that the calculated concentration in the fish are generally within the range of reported data within Figure 8. It appears, however, that the alewife have been exposed to a lower water concentration since the observed values shown in Figure 8 are below  $10 \mu\text{g/g}$ . Figure 9 shows that for alewife this would represent exposure at a level of about  $0.01$ - $0.02 \mu\text{g/l}$ , the lower end of the reported range. This may represent entrance by alewife into Waukegan Harbor after exposure at lower Lake Michigan concentrations.

The principal conclusion from Figure 9 is that water concentrations must reach levels of about  $0.01$ - $0.02 \mu\text{g/l}$  dissolved PCB in the water in order to have these representative species reach levels of PCB of about  $5$ - $10 \mu\text{g/g(w)}$ . As shown in other sections of this report, the  $0.01$ - $0.02 \mu\text{g/l}$  dissolved PCB range is approximately attainable by dredging of the highly contaminated sediments of the Harbor.

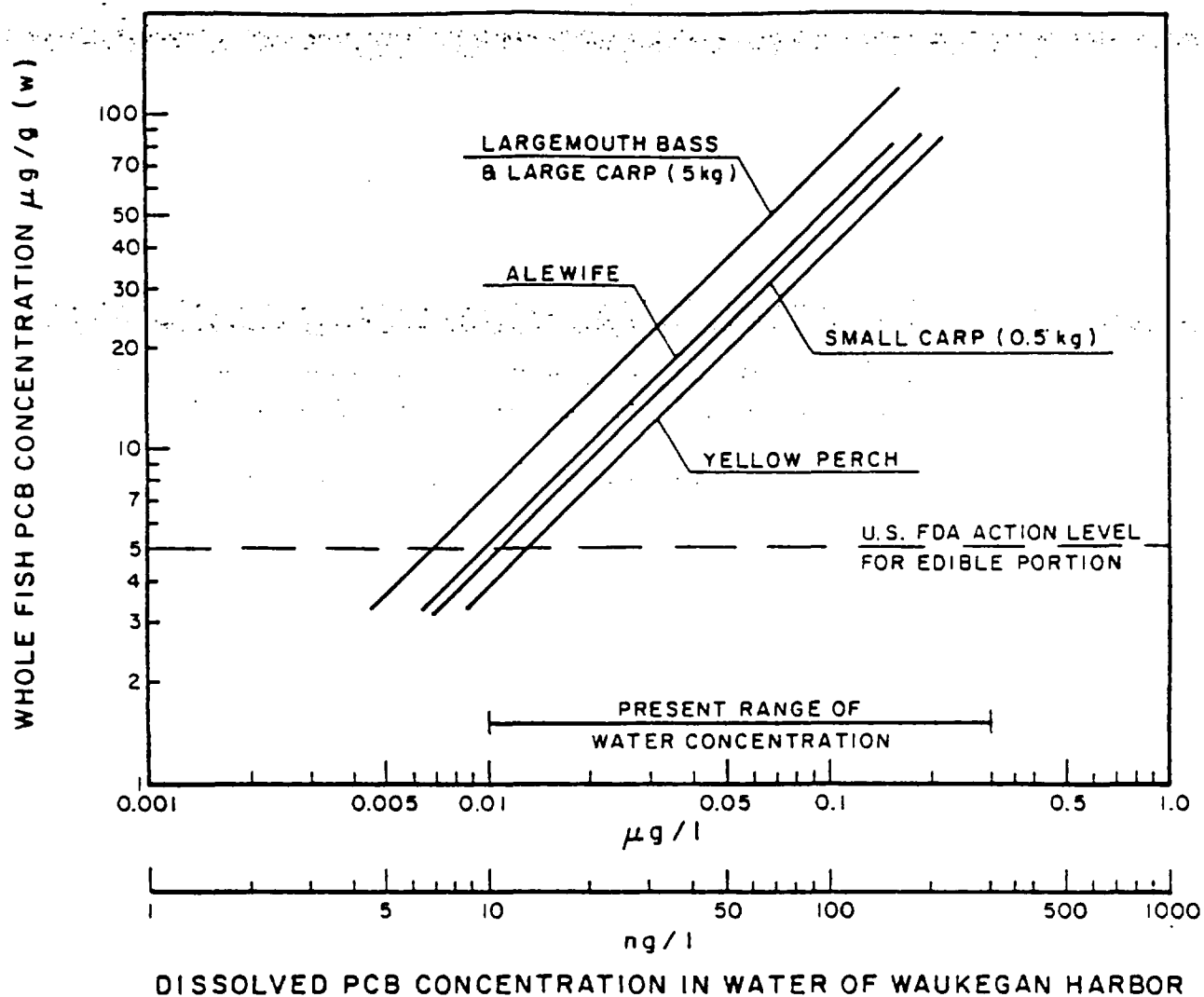


FIGURE 9

ESTIMATED RELATIONSHIP BETWEEN PCB CONCENTRATION  
IN FISH OF WAUKEGAN HARBOR AND WATER PCB CONCENTRATION

Overall, the following conclusions are drawn from an analysis of the fish PCB data:

1. About 80% of the reported PCB concentrations for whole body Harbor fish exceeded the US F. D. A. level of 5 µg/g(w) for the edible portion. The maximum value was 187 µg/g for a largemouth bass and the range of data is representative of highly PCB impacted areas such as the Hudson River.
2. The food chain model calculations indicate that in order to reduce the present fish PCB body burden in Waukegan Harbor, the presently observed water column PCB concentrations of about .01-.3 µg/l must be reduced to the levels of .01-.02 µg/l within the Harbor.

## 2.4 The No Action Alternative

Under this plan no effort or expenditures will be made to either reduce the existing level of the PCB contamination or prevent its migration in the physical and biological components of the environment. It could include, however, taking measures to mitigate the harmful effects of the contamination such as banning fishing in the Waukegan Harbor and nearby areas of Lake Michigan and also restricting boat traffic in the source waters.

### 2.4.1 Longevity of Problem

Since the no action alternative leaves the present conditions of PCB contamination unchanged the question of persistence of the present conditions arises. To address this question a mathematical water quality model of the Waukegan Harbor as described in Section 4.2.3 was used to calculate the flux of PCB from the Harbor to Lake Michigan. The analysis showed that there was no change in the PCB flux to the lake over a five year period. During the same time the calculated bottom surface sediment PCB concentrations did not change. As noted in section 1.2.1.1, Figure , surface sediment concentrations collected during 1976 to 1978 showed no reduction in PCB contamination in comparison to data collected in 1979. It is expected therefore that the present PCB flux from the Harbor to the Lake will persist for a very long time, that is, longer than 10 years. Furthermore, no significant reduction in the PCB Harbor sediment concentrations is expected for 10 years or more.

#### 4.1 The No Action Alternative

As it was detailed in Section 2.4.1, under the no action alternative, the present levels of PCB contamination and PCB fluxes will persist for a very long time, longer than 10 years. The most severely affected area, outside the Harbor/Ditch system, will be the Waukegan coastal zone adjacent to the Harbor. The water column, bed sediment and the biota associated with the coastal zone will continue to be impacted by the calculated 22-44 lbs/yr PCB flux for a very long time.

#### 4.2.2 Diversion of Water

Previous evaluations of Waukegan Harbor included a water withdrawal of 3 MGD from the Harbor by the Outboard Marine Corporation. It is proposed (USEPA<sup>(1)</sup>) that during the dredging operations this withdrawal will be stopped and that for the duration of the operations Outboard Marine Corporation will be connected to the public water supply system of the City of Waukegan. Therefore, for the purpose of estimating the impact of the dredging operations to Lake Michigan, further analyses will not contain any water withdrawal from the Harbor.

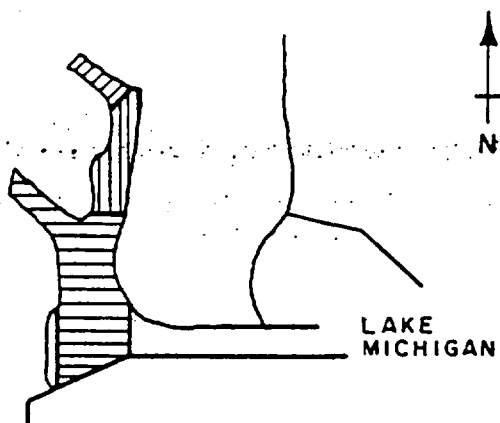
#### 4.2.3 Harbor Dredging

Dredging the Harbor bottom sediments has been proposed as a part of an action plan to contain and eventually eliminate the sources of PCB contamination. The dredging alternatives are as follows:




- I Dredge all areas where the bottom sediment PCB concentration is in excess of 500 ppm.
- II In addition, dredge all areas where the bottom sediment PCB concentration is between 50 and 500 ppm.
- III Dredge all areas where the bottom sediment PCB concentration is between 10 and 50 ppm.

Figure 10 shows the areas of the Harbor affected by each dredging alternative. Alternative I involves essentially the dredging of Slip 3, Alternative II in addition to slip 3 includes the dredging of the upper half of the N-S section of the Harbor, while Alternative III involves the lower half of the N-S section of the Harbor.

In order to evaluate the effectiveness of the foregoing alternatives, a water quality model of Waukegan Harbor developed by HydroQual (1981) was used. The model of Waukegan Harbor is a mathematical representation of dilution, dispersion, flow and



**LEGEND:**

-  OVER 500 PPM
-  50 TO 500 PPM
-  10 TO 50 PPM

**REFERENCE:**

ADAPTED FROM MASON & HANGER 1981

**FIGURE 10**  
**EXTENT OF PCB CONTAMINATION OF WAUKEGAN HARBOR SEDIMENTS**

other physical-chemical processes and conditions governing the spatial and temporal distributions of PCB and other selected water quality constituents. The Waukegan Harbor model was calibrated with available data collected in Waukegan including chlorides, dye, and suspended solids to assess the dispersional and transport characteristics of the Harbor area and the interaction of the water column with PCB laden bottom sediments. The model was also calibrated to relate water column PCB concentration and therefore flux to Lake Michigan to observed sediment PCB concentrations. Thus, although an approximation, the model can be used to assess the effect of changes in bottom sediment PCB levels as a result of dredging on water column PCB concentrations and Harbor losses to Lake Michigan. A similar model was developed for the North Ditch area.

With the modeling framework, two types of scenarios were examined:

- i. The long term impact of dredging on conditions in Waukegan Harbor and Lake Michigan.
- ii. The impact on Waukegan Harbor and Lake Michigan during the dredging operations.

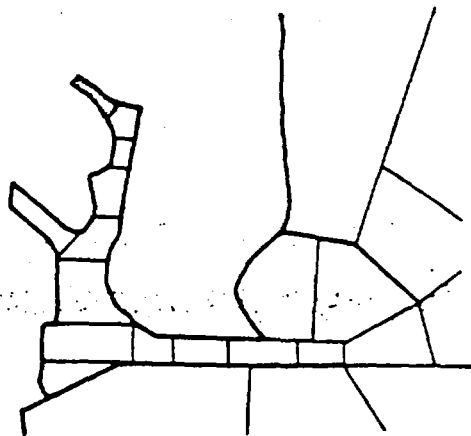
Each type is discussed below.

#### 4.2.3.1 Long Term Impact to Lake Michigan

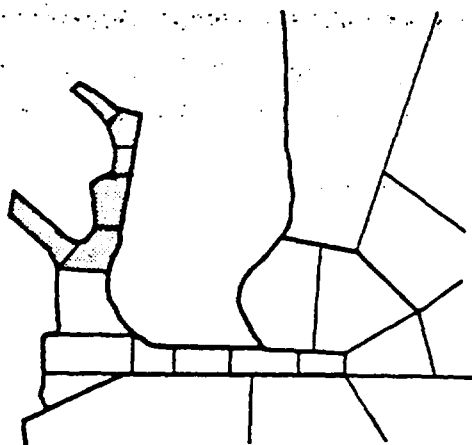
Under this scenario, it is assumed that dredging operations have been completed and that any transient effects due to dredging operations have subsided. The purpose of this analysis therefore is to assess the significance of removal of PCB laden sediments on water column and fish concentrations in Waukegan Harbor and the flux of PCB to Lake Michigan.

Figure 11 shows the segments of the Waukegan Harbor model which are affected by each of the foregoing dredging alternatives. In each case the sediment PCB concentration of the shaded segments was set to the final sediment PCB concentration (10, 50, 100 and 500  $\mu\text{g/g}$ ) which could result from dredging operations. The unshaded segments retained the present sediment PCB concentrations.

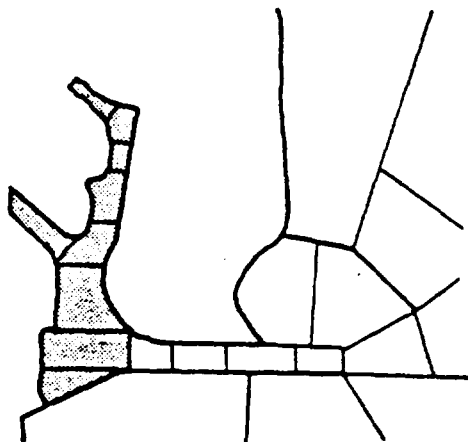
Three major sets of simulations were run with the Waukegan Harbor model; one for each of the dredging alternatives shown in Figure 12. In turn, it was assumed that for each dredging alternative, the final sediment PCB concentration after dredging was either 10, 50, 100, or 500  $\mu\text{g/g}$ . Thus, in all, twelve combinations were investigated; three alternatives of various aerial extent, and four resulting sediment PCB concentrations.



ALTERNATIVE I



ALTERNATIVE II



ALTERNATIVE III

FIGURE 11

BOTTOM SEGMENTS OF WAUKEGAN HARBOR MODEL  
AFFECTED BY THE DREDGING ALTERNATIVES

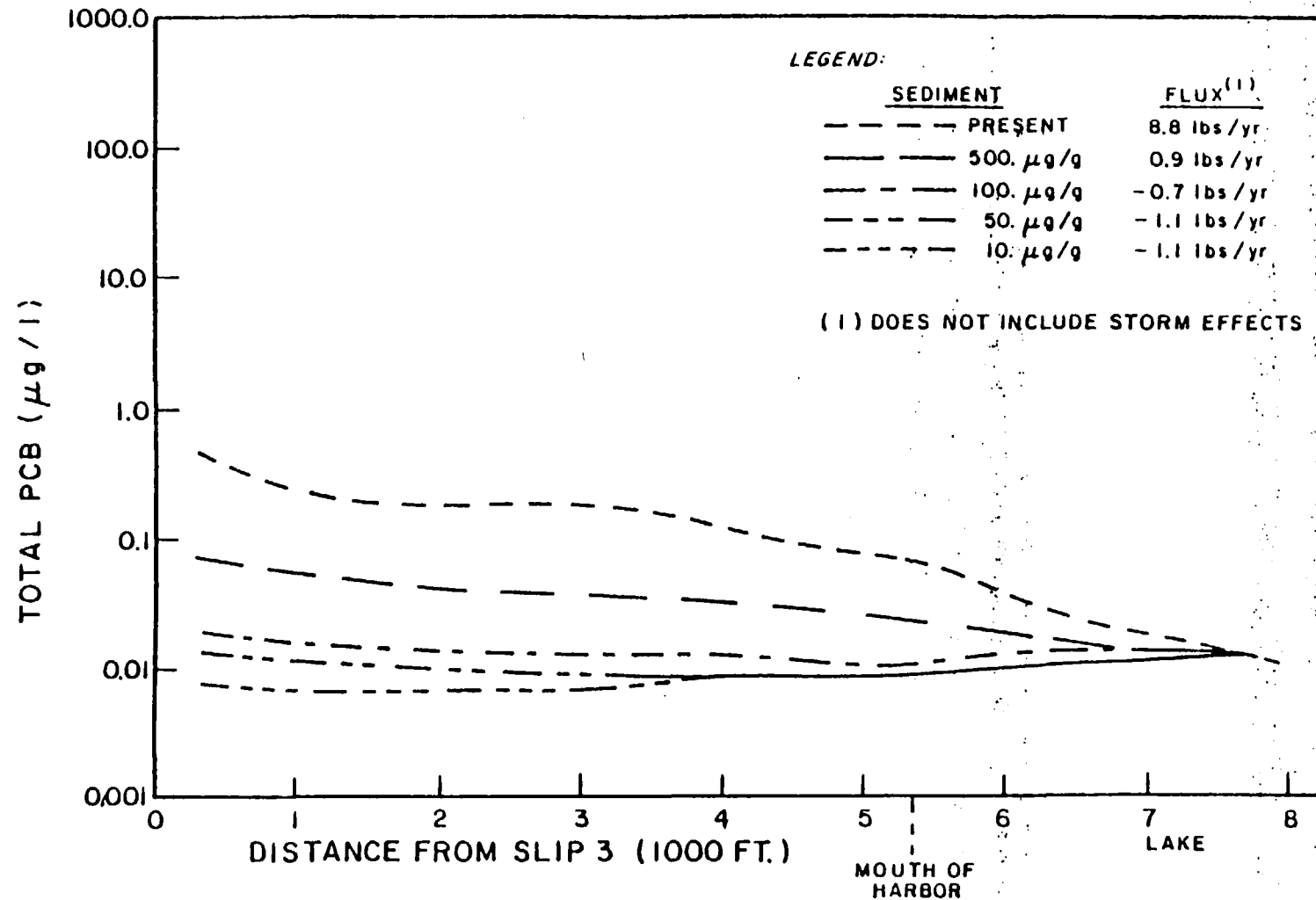


FIGURE 12

ESTIMATES OF THE IMPACT OF DREDGING  
ON PCB WATER COLUMN CONCENTRATIONS

On the basis of the modeling analysis and the characteristics of Waukegan Harbor as determined from available data, the following observations are presented:

1. It appears that the most effective dredging procedure from the standpoint of reducing water column PCB concentration and flux to Lake Michigan is Alternative I, the dredging of Slip 3. On the basis of the modeling analysis, the characteristics of Waukegan Harbor are such that due to the extremely high sediment PCB contamination and high apparent interaction with the water column, Slip 3 appears to be the most responsible area for presently observed conditions of water column contamination and flux to Lake Michigan. As a result, remedial action in this area may be more effective in reducing these impacts.
2. The PCB sediment concentrations remaining after dredging appear to be more significant in terms of reducing the water column PCB concentration and PCB flux to Lake Michigan than the spatial extent of dredging. This is indicated in Figure 12. It shows the calculated Waukegan Harbor water column PCB concentration and resulting flux to Lake Michigan for various residual sediment PCB levels in Alternative I (dredging of Slip 3) as compared to present conditions. These results indicate that if residual sediment PCB levels of 10, 50, or 100  $\mu\text{g/g}$  can be attained in Slip 3, a substantial reduction from present conditions in both water column PCB and flux to Lake Michigan will result. Water column PCB will be reduced by more than an order of magnitude from 0.3 - 1.0  $\mu\text{g/l}$  to approximately 0.01  $\mu\text{g/l}$ . The steady state flux to Lake Michigan from the Harbor would be reduced from the present level of 8.8 lbs/yr to approximately zero. Other transient events, however, would probably still contribute some discharge of PCB to the Lake but at levels less than 2 lbs/yr.
3. If residual sediment PCB concentrations can be reduced to only 500  $\mu\text{g/g}$ , water column PCB concentrations are estimated to be reduced to approximately 0.05  $\mu\text{g/l}$  for most of the harbor area. There will continue to be some steady state flux to Lake Michigan of about 0.9 lbs/yr or so, in addition to less than 2.2 lbs/yr from storm induced flushing.
4. The most effective alternatives from the standpoint of the Waukegan Harbor fishery as analyzed in Section 1.2.4.2 are those which reduce water column PCB levels to the 0.01 to 0.02  $\mu\text{g/l}$  range, ultimately reducing fish burdens to near US F. D. A. action levels. This would require that residual sediment PCB levels of 10 to 100  $\mu\text{g/l}$  be attained at least in

Slip 3. If residual sediment levels of 500 µg/g remain, water column concentrations in Waukegan Harbor are estimated to be approximately 0.05 µg/l with fish body burdens remaining in the 20 to 40 µg/g (w) range.

5. Although most of the positive impacts described above are associated with dredging activity in Slip 3 (Alternative I), it should be recognized that there are other factors operative in the Harbor, such as localized transient turbulent effects and sediment motions that are not included in the analysis framework. As discussed above, dredging Slip 3 to residual sediment PCB levels of 10 to 100 µg/g will result ultimately in substantial improvements in water column concentration and fish body burdens, and flux to Lake Michigan. It is possible, however, that downstream harbor sediments outside Slip 3 could re-contaminate the Slip 3 area as a result of periodic natural turbulence and thus reduce the initial effectiveness of dredging. The extent of this possibility, however, cannot be quantified at this time.

#### 4.2.3.2 Impact to Lake Michigan During Dredging Operations

According to the dredging plan (Mason & Hanger, 1981), the bottom sediments of Slip 3 will be dredged first by means of either a hydraulic or pneumatic dredge. Before dredging begins, all water withdrawals from the Harbor will stop, and a double silt curtain will be placed between Slip 3 and the rest of the Harbor in order to minimize the spreading of the roiled sediments resulting from the dredging. The bottom of the double silt curtain will be sunk into the muck layers and there will be a 2 ft-wide gap between the end of the curtain and the bank.

It is estimated (USEPA) that during the dredging of Slip 3 the total PCB concentration in the water column within slip 3 may vary, depending on the distance from the dredge, between 500 and 5,000 ppb, the latter being the worst case situation. In the model simulation of the dredging operations it was estimated (USEPA) that the worst case total PCB concentration most likely to occur at the location of the silt curtain is about 500 ppb. It appeared reasonable to assume that when the dredge was operating on the highly contaminated sediments of the inner part of Slip 3 the high total PCB concentration (5,000 ppb) might occur in that area of the slip and the roiled sediments would settle quickly so that the concentration at the silt curtain would be attenuated to about 500 ppb. Also, when the dredge was operating at the closest-but-yet-safe distance from the silt curtain in the outer part of Slip 3 where the sediments are not as heavily contaminated, the total concentration at the silt curtain may be taken as 500 ppb. Therefore, Slip 3, for purposes of a model simulation, was considered to have a total PCB concentration of 500 µg/l.

The cross-sectional area at a location between Slip 3 and the rest of the Harbor was reduced to represent only the 2 ft-wide gaps on the side of the silt curtain. The water withdrawal of about 3 MGD was stopped and the discharge from the dewatering lagoon (1,500 gpm or 3.3 cfs) was included with 1 µg/l total PCB concentration, as described below. The calculated resulting flux of PCB from the Harbor to Lake Michigan remained constant, at about .13 lb/d or 47.5 lbs/yr. This temporary flux is about the same as the estimated flux from the Harbor/Ditch under the no action alternative. It should also be noted that this estimate should be viewed as a worst-case estimate insofar as the dredging and treatment operations occur simultaneously.

#### 4.2.4 Operation of the Dewatering Lagoon

The construction and operation of a dewatering lagoon is an integral part of the dredging plan of action. The purpose of the lagoon is to hold the dredged sediments. The lagoon will be constructed near the harbor and probably on OMC property. Depending on the final version of the dredging plan one or more lagoons may be needed to hold the sediments. The design capacity of lagoons will also accommodate any additional volume of water due to rainfall.

Following the construction of the lagoon and before dredging commences, the lagoon will be filled with water to test its structural integrity. Following the test, the water from the lagoon will be withdrawn and the lagoon will be empty at the time the dredging operations begin. The slurried sediment resulting from the first phase of the operations will be conducted to the empty lagoon and will be allowed to settle. The supernatant from the lagoon will be treated for PCB removal by polymer addition, sedimentation, and carbon filtration. The details of the treatment process are described in the action plan (Mason & Hanger, 1981). The effluent water of the treatment process will be returned to the Harbor at total PCB concentration of 1  $\mu\text{g/l}$ . It is presently estimated (USEPA) that the majority of the effluent water will be discharged at steady flow rate of 1,500 gpm, which will decline at the latter stages of the operations. The duration and timing of the dredging and treatment operations are estimated to have an overlap period with the dredging occurring first, the treatment process most likely will continue after all dredging has finished.

Assuming (i) that about 95% of the sediments in the areas affected by Alternatives I and II are dredged in order to achieve a final sediment concentration of 50  $\mu\text{g/l}$  and (ii) that these sediments are slurried to 15% by volume, then the volume of the water to be treated is 320,000 cu. yds. Assuming that 90% of this volume will be discharged @ 1,500 gpm, the duration of the 1,500 gpm effluent discharge is estimated at about 1 month. The load to the Harbor during this month is about .02 lb/d. And the total mass of PCB discharged to the Harbor is estimated as about .5 lb or, say  $\leq 1$  lb.

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